XIV. *Notes in* 1886 *upon lepidopterous larvæ, &c.* By EDWARD B. POULTON, M.A., F.L.S., F.G.S., F.Z.S., of Jesus and Keble Colleges, Oxford.

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PLATE X.

CONTENTS.

1. NOTES UPON THE YOUNG LARVÆ OF SMERINTHUS POPULI, AND UPON THE RED SPOTS IN SMERINTHUS LARVÆ:— *α. The markings of the young S. populi larva.*—A young yellowish green larva of this species was carefully examined when it was advanced in the second stage, and 13 mm. long when extended at rest. It possessed the red spot on two of the segments, but a description of this feature will be found below. At this stage the yellow marginal lines of the face terminate upwards in

two apical tubercles, which are especially large but not predominant, and are without any distinctive colour. Two dorsal tubercles are especially distinct upon the second and the third thoracic segments, continuing anteriorly the direction of the barely recognisable eighth stripe, as in the young *Sphinx ligustri*, in which, however, the marking is far more distinct and persistent. A semicircular crown, of especially large tubercles, extends in the vertical plane immediately behind the head upon the most anterior annulus of the first thoracic segment. There are about fifteen tubercles in the semicircle, and they are directed forwards, and produce a very striking effect. The first and seventh stripe are especially large and distinct; the stripes and the subdorsal are chiefly made up of tubercles, but there is some suffusion of the ground colour, which is (as usual) complete in the posterior part of the seventh stripe upon the eighth abdominal segment. The first stripe extends anteriorly as a line of tubercles on to the thoracic segments, becoming at first horizontal and parallel with the subdorsal, but appearing to rise on the first thoracic segment, and joining the ends of the semicircular crown; but in the anterior part of its course the line becomes very difficult to follow. The seventh stripe is also continued forward to the anterior limits of the sixth abdominal segment. There are oblique stripes (chiefly made up of shagreen dots) just above the claspers on the third, fourth, and fifth abdominal segments. These lines are more nearly horizontal than the ordinary oblique stripes, and their relation to the latter is doubtful. They may represent the forward extension of the fourth, fifth, and sixth oblique stripes (respectively), but they have also the appearance of a subspiracular line twisted into partial parallelism with the oblique stripes. Hence an examination at this stage adds nothing to our knowledge of these lines, which are also found during the whole subsequent life of the larva, and which I have previously described in the last stage (Trans. Ent. Soc. Lond., 1885, Pt. II. (Aug.), p. 297). The extension of the first stripe and the semicircular crown are not equally distinct in later stages, but the latter is easily recognisable. The eighth stripe disappears. The whole comparison strongly confirms Weismann's conclusion as to the extreme uniformity, and therefore the ancestral character, of the appearances witnessed in the ontogeny of this species.

β. *The young larva of Sesia bombyliformis, &c.*—I have found a note, in Prof. Westwood's 'Modern Classification of Insects' (1840, vol. ii., p. 366), which proves that the yonng larvæ of the genus are spinous, and thus resemble all the other young *Sphinx* larvæ which have been examined for this character. At that time the character had not been described in any other of the *Sphingidæ*, and therefore Prof. Westwood looked upon the genus as aberrant. The note is as follows:—"*Sesia* (*S. bombyliformis*, &c.) is certainly the most aberrant genus in the family, the caterpillars being slightly pilose; and when about ten days old they have several furcate spines upon each segment of the abdomen that entirely disappear when they are full-fed, according to the information given by Mr. Dale to Mr. Curtis. The full-grown caterpillar is, however, evidently Sphingideous." The fact that the spines are furcate compares in an interesting manner with the character of these structures in the genus *Smerinthus*.

γ. *Further notes upon the red spots of Smerinthus larvæ:*—i. *Smerinthus ocellatus.*—In two mature larvæ, captured in August, 1886, the red spots were more developed than in any other individual of this species hitherto described. Both were light yellowish green varieties, although not extreme forms, and both were found upon *Salix triandra* near Oxford. The most extreme variety is represented in Plate X., fig. 1; but the other only differed in the absence of the minute dot of the upper row on the first thoracic segment. The small size of the upper dot on the seventh abdominal segment is noteworthy, and was the same in both individuals. Comparing these larvæ with that figured in one of my previous papers (Trans. Ent. Soc. Lond., 1884, Pt. I., p. 27, &c.), it is seen that in the larvæ here described the spots of the two upper rows are larger and extend on to more segments, while those upon the claspers are much larger and more distinct. In breeding large numbers of this species I found the spots in various degrees of development upon many of the whitish larvæ, although more frequently upon the yellowish varieties. This observation confirms the single instance of a spotted whitish larva, which I recorded last year.

ii. *Smerinthus populi.* — I have had the opportunity of making notes upon the red spots upon larvæ in early stages. Seven young larvæ, fed upon *Populus nigra*, were kindly given me by Mr. A. Sidgwick, of which, on July 15th, the youngest (No. 1) was advanced in the second stage, and 13 mm. long when extended at rest. It was a bright yellowish green variety, and possessed distinct red spots on the third abdominal, and very minute ones on the second thoracic segment. The other six larvæ were changing their skins for the second time, and they were all about 15·5 mm. long. Two larvæ were yellowish green (but not extreme forms), of which one (No. 2) had large spots on the third abdominal and on the second thoracic segments, the former being the larger; there were also very small spots on the fourth abdominal, and still smaller on the first abdominal. The other larva (No. 3) had very small spots on the third abdominal only. Four larvæ were bluish green, two being more distinct varieties; and of these one (No. 4) had rather large spots on the third abdominal only, the other (No. 5) having no traces of the spots. Of the two remaining larvæ—less decided varieties of the same colour—one (No. 6) possessed distinct but rather small spots on the third abdominal, smaller and less distinct spots on the first abdominal, and far smaller, so as to be hardly visible, on the second thoracic segment. The other larva (No. 7) had well-developed spots on the third abdominal only. On July 18th the larvæ were re-examined. No. 1 was changing its second skin, and the red spots were much less distinct, although visible. The other six larvæ had now entered the third stage. No. 2 possessed large and distinct spots on the third abdominal, and small, although distinct, spots on the second thoracic segment, while there were very faint and minute ones upon the fourth abdominal. No. 3 had lost all traces of the spots. No. 4 possessed a spot on the left side only of the third abdominal. No. 5 was as before. No. 6 had the merest trace upon the third abdominal only. No. 7 was as before.

These observations certainly confirm Mr. William White's observations upon the comparatively early appearance of these features, but they also conclusively show that the characters do not necessarily develop in the successive stages, but that they may gradually decrease and disappear in the course of development, just as if they were features of phylogenetic significance only. Extended observation will, I feel sure, confirm this conclusion, and will prove that the spots are present upon a much larger proportion of young larvæ than upon those in the later stages, although it is well known that in a certain proportion of the latter the character reaches a pitch of perfection which has not been hitherto described in the earlier stages. The first appearance of the spots upon the third abdominal segment, and then upon the second thoracic, has already been proved by Mr. White,—a conclusion which is abundantly confirmed by my observations.

On September 21st I found two larvæ of this species upon balsam poplar at Bembridge (Isle of Wight). Both possessed the spots to a remarkable extent. One larva was about half-grown in the last stage, and was of a yellowish green ground colour. The other was adult, and a very white variety, exactly resembling in ground colour that figured by Mr. Bignell, and represented in my paper (Trans. Ent. Soc. Lond., Pt. I., April, 1884). The spots of the upper row in both larvæ are arranged below in the order of relative magnitude, the largest spots being numbered first:—

Yellow larva—(1) abdominal, 7; (2) abdominal, 3; (3) abdominal, 4; (4) abdominal, 2 and 5; (5) abdominal, 1; (6) thoracic, 2; (7) thoracic, 3; (8) thoracic, 1, and abdominal, 6.

White larva—(1) abdominal, 3; (2) abdominal, 4 and 7; (3) abdominal, 5 and 2, and thoracic, 2; (4) abdominal, 1; (5) abdominal, 6, and thoracic, 1 and 3,—all these very small.

There was also a reddening of the upper side of the base of the horn in both larvæ.

Nos. (1) and (2) of the yellow larva were almost equal, so that the spot which appears first in the young larva is one of the largest in the adult, but the same comparison does not hold with the spots which appear next in order. It is strange that the spots should be so large upon abdominal 7, for in *S. ocellatus* this segment is remarkable for the minute size of its spot, which is only present in extreme varieties. Furthermore, in *S. tiliæ* the red band or spot was remarkably small upon this segment. Hence it is probable that *S. populi* is abnormal in this respect. The larvæ here described probably indicate that the spots in the larva already referred to, as figured by Mr. Bignell, are represented as too numerous in the anterior part of the body, for in neither of these extreme varieties did the number of spots in any row ever exceed the number of the segments.

The spiracular row of spots was well marked in these larvæ, and a small spot appeared on the third thoracic segment and a larger one upon the second in the yellowish larva; the latter spot being well developed in the whitish larva, but the former and that around the prothoracic spiracle could not be seen when the larva was examined (perhaps because it was examined somewhat late, after the changes of colour before pupation had commenced).

The claspers were all marked, but this row was not well developed, the spot on the anal clasper of the yellowish larva being especially small.

A character, new to me, was the extension of the system on to the head. The head of the yellowish variety is represented from the left side in Plate X., fig. 2, × 2 diameters. The chief colour is on the area of the ocelli, and it extends over the marginal line as a linear vertical mark on the face. The apex is also suffused, the colour extending on to the sides of the upper part of the face. The red tint formed the ground colour, for there were no red apical tubercles. The whitish larva possessed the ocellar and apical red areas, but not the extension of the former.

On July 6th I had the opportunity of examining a number of larvæ, reared by Mr. Arthur Sidgwick from a single batch of eggs, and all fed under the same conditions of light, and with the same food—*Populus nigra* and balsam poplar. The colours and development of spots is seen to be very heterogeneous.

Stage of larva.	Tint of ground colour.	Red spots.
1. Beginning of last stage.	Bright yellowish green.	*Upper row.* — Spot on 3rd abdominal; slight suffusion of spiracles on abdominal segments 2, 3, 4, 5, and 6 of right side; and left, on the 1st and 7th abdominal, as well.
1. ,, ,,	,, ,, ,,	No spots.
1. Near beginning of last stage.	,, ,, ,,	,, ,,
1. Small (in stage 3 or 4).	Rather yellowish.	,, ,,
1. Almost mature.	Yellowish, but not extreme.	,, ,,
3. ,, ,,	Bluish green.	,, ,,
4. Small, in last stage.	,, ,,	,, ,,
3. ,, ,,	On bluish side of an intermediate variety.	A spot on the side of 3rd abdominal only.
3. Almost mature.	,, ,, ,,	No spots.
1. ,, ,,	Intermediate.	,, ,,
1. Small, in last stage.	,,	,, ,,
3. Changing 3rd or or 4th skin.	Bluish green.	,, ,,
2. ,, ,,	Intermediate.	,, ,,
1. Advanced in last stage.	On bluish side of an intermediate variety.	,, ,,
2. Small, in last stage.	On yellowish side of an intermediate variety.	,, ,,
1. ,, ,,	,, ,, ,,	Spot on 3rd abdominal, and the faintest suffusion of the middle abdominal spiracles.

iii. *Smerinthus tiliæ.*—During the past summer I reared a large number of larvæ from a single batch of eggs obtained from a captured female. Many of the larvæ possessed the red markings, which seemed to be extremely linear on their first appearance, forcibly reminding me of the earliest traces of purple borders in *Sphinx ligustri*. As the larvæ entered the later stages the red borders contracted and became broader, finally assuming the well-known appearance of somewhat elongate spots on the anterior margin of the oblique stripes. I have already mentioned the relatively slight development of the red marking upon the seventh abdominal segment. This observation of the primarily linear appearance of the spots seems to indicate that these features in *S. tiliæ* have arisen from a modification of a normal coloured border, as I suggested last year (Trans. Ent. Soc. Lond., 1886, Pt. II., p. 139):—"It seems possible that the appearances seen in *Smerinthus tiliæ* are due to a fading away of the character (*i.e.*, coloured borders) instead of its origin. In the other *Smerinthus* larvæ the shortening borders may have been arrested at the spot-stage, which has evidently been made use of as an independent larval marking, and which has received additions in the other rows."

2. Description of an unnamed Sphinx larva from Celebes. — My friend Dr. S. J. Hickson, of Downing College, Cambridge, very kindly brought me a well-preserved specimen of a mature Chærocampoid larva from Celebes. The larva is represented in Plate X., fig. 3 (natural size), and is extremely interesting in uniting the characteristics of several genera of the *Sphingidæ*. In the first place it possesses the terrifying eye-like marks on the first abdominal segment, although there is no trace of similar markings on any of the other segments. In the genus *Chærocampa* (and in closely allied genera) the chief terrifying marks are upon the same segment, but there are generally other smaller marks on the second abdominal and sometimes also on the third thoracic segments, while in many species traces of the marks are repeated on abdominal segments 3—8. The marking itself consists of a small and narrow black "ground area," a normal white "mirror," and an intensely black "nucleus," within which again are some minute white markings. The only other larva I can find described with but a single terrifying mark (similarly placed) is *Pergesa mongoliana* (A. G. Butler, Trans. Zool. Soc., vol. ix., part x., 1876). It appears probable that a single pair of such markings,

appropriately placed and highly conspicuous in the terrifying attitude, must be at least as efficient in causing alarm as a greater number of markings. And as a matter of fact, in Prof. Weismann's figure of *C. porcellus* in the terrifying attitude, it is shown that the single pair (which are by far the largest) on the first abdominal segment are prominent and alone produce any effect, the marks on the second abdominal segment being insignificant and partially concealed, while the marks repeated on other segments are of great morphological interest, but of no functional importance. Dr. Hickson informs me that the terrifying attitude was very perfectly assumed by the larva, as we should expect from the tapering of the body anteriorly and the small head, by which the complete retraction into the part possessing the eye-like marks is rendered possible. All this is typical of *Chærocampa*. It is noteworthy that the anterior part of the marking extends on to the third thoracic segment. The marking occurs as an interruption of the subdorsal line, thus indicating its origin from the latter, as Prof. Weismann has shown, and the line itself persists faintly along its whole length, existing as a lightish and often interrupted stripe immediately below the line in which the rather darker ground colour of the dorsal area terminates. This arrangement very much resembles that which I have previously described in *Smerinthus*. The ground colour was green, as in the young stages of *Chærocampa*, and in a small proportion of the mature larvæ (in the two English species), but it retains distinct traces of shagreening over the whole surface, and the caudal horn is sprinkled with typical hair-bearing tubercles. The persistence of the shagreen dots upon the horn resembles *Acherontia* (and other genera), but the general surface of the larva has far more distinct traces of these structures than are found in this genus. Very large white dots remain on the sides of the third thoracic and first abdominal segments, in the same situation which is marked by a conspicuous light patch in *Chærocampa elpenor*. The shape of the caudal horn is peculiar, but very unlike that of *Chærocampa*, being large and strongly curved downwards towards the apex, and tapering very suddenly close to the point into a conical form. Except in the last point, which, as far as I know, is peculiar, the shape of the horn suggests *Sphinx*, just as its surface suggests the closely allied genus *Acherontia*. There are six oblique white stripes on the sides, with distinct anterior borders formed of darkened ground colour, while the borders are faintly continued on to the dorsal area, and above the subdorsal tend to meet in a series of Vs. This latter suggestion of the first and "eighth stripe" is also present in the normal position, and the whole arrangement almost exactly recalls that of *Smerinthus* and the early stages of *Sphinx ligustri*. Thus the seventh stripe is especially prominent, and runs up into the base of the caudal horn, while the posterior part of the subdorsal is continuous with the stripe, exactly as in the above-mentioned genera. This remarkable union of characteristics of such different genera serves to indicate the morphological identity of the faint oblique stripes of *Chærocampa elpenor* and of *C. porcellus* with the more distinct markings of *Smerinthus* and *Sphinx*, and I have little doubt that these features will be found to exist in the younger stages of *Chærocampa*, when they are examined with this object in view. The last character is an extremely ancestral feature,—the permanence of the dorsal tubercles which I have described in the younger stages of *Sphinx* and *Smerinthus*. These persist as two pairs of white marks upon the dorsal surface of the abdominal segments in front of the eighth; white spots also occur on the dorsal surface of the thoracic segments. Traces of at least one of the two lateral tubercles can also be faintly made out as an especially white part of each stripe above and rather behind the spiracle. Since my description of these tubercles in young *Sphinx* larvæ a paper has appeared by Dr. Wilhelm Müller ("Südamerikanische Nymphalidenraupen," 'Zoologischen Jahrbüchern,' J. W. Spengel. Jena, 1886), in which he describes the same tubercles in larvæ of many widely-separated groups, and calls them the "primitive tubercles." Before I read his paper I had also recognised them in many different larvæ, and had regarded them as very primitive features. In fact, I had discussed with Prof. Meldola my intention to work out these characters, which are common to widely-separated larvæ, and from them to endeavour to reconstruct, as far as possible, their arrangement in the ancestral larva. Dr. W. Müller has, however, now worked out the arrangement of the primitive tubercles very completely, and I only mention my own observations in connection with the subject as an entirely independent confirmation of his conclusions. I think it is extremely probable that the white spots occurring in pairs upon the dorsal surface of the mature larvæ of *Chærocampa elpenor* and *C. porcellus* (figured by Weismann) represent one of the two pairs (probably the posterior) of the dorsal primitive tubercles. If this be the case they will be found, with the other pair, at earlier stages of the ontogeny, and will be found to assume the appearance of tubercles. Although the traces of the primitive tubercles merely take the form of white patches in Dr. Hickson's larva, yet there is no other *Sphinx* larva hitherto described in which the position of so large a part of the primitive characters are distinctly indicated in the later stages. The ontogeny of such a larva is probably extremely uniform.

3. Further observations on the protective attitude of Geometer larva :—α. *The spiral or irregular position assumed by young larvæ resting on leaves.*—I am now able to add observations of two species, in addition to those previously described. The young brown larvæ of *Selenia lunaria* twist themselves into an irregular spiral when seated on the leaves of their food-plant, and this attitude is sometimes assumed by the mature larvæ when resting in such a position. The young brown larvæ of *Rumia cratægata* also have the same habit, generally sitting on the edge of a leaf close to the piece which they have eaten out of it. In this position the larva suggests most strongly the appearance of a small part of the leaf which has been injured in some way, and has curled up and turned brown, but still remains adherent by one end to the uninjured part of the leaf.

β. *The supporting thread sometimes dispensed with in the twig-like attitude.*—Although the almost invisible thread is invariably made use of in all the most perfect and elaborate resemblances to twigs, I have observed that in an effective and well-concealed form of this protective appearance the larva (in the case of *A. betularia*) is supported in another way, *viz.*, by holding a branch, leaf-stalk, or leaf in the clasp of its thoracic legs. Thus the larva often presents the appearance of a twig passing obliquely from one branch to the other, and, although such a position seems likely to attract attention because it represents something unnatural, yet in reality the concealment is very perfect, for the twigs of the food-plant (birch) are so extremely numerous, and present such a complicated network to the observer, that one such oblique twig-like appearance readily escapes detection, and may often fall into the line along which a real twig is prolonged. Very commonly the larvæ are supported anteriorly by holding the leaves or stem of the branch to which the claspers cling, and in this case the concealment among the interlacing twigs of the food-plant is even more perfect. It is probable that the same mode of support will be found to hold good in other species of *Geometræ*. The attitude is shown in Plate X., fig. 4, a green variety of *A. betularia* being figured on a twig of birch.

γ. *The softening of the contact between a Geometer larva and the twig on which it is resting.*—In a note to the translation of Weismann's 'Essay on the Markings of Caterpillars,' p. 292, Prof. Meldola states as follows:—"The adaptive resemblance is considerably enhanced in *Catocala* and in *Lasiocampa quercifolia* by the row of fleshy protuberances along the sides of these caterpillars, which enables them to rest on the tree-trunks by day without casting a sharp shadow. The hairs along the sides of the caterpillar of *Pœcilocampa populi* doubtless serve the same purpose." This explanation, which had been previously given by Professor Meldola, is accepted by Sir John Lubbock (Trans. Ent. Soc. Lond., 1878, p. 242) and by Mr. Peter Cameron (*ibid.*, 1880, p. 75), and the latter writer extends the explanation to the hairy larvæ of certain phytophagous Hymenoptera. I can now bring forward a confirmatory observation which supports the explanation offered by Prof. Meldola in the strongest manner. The larvæ of *Geometræ*, in the typical attitude of protective resemblance to a twig, only touch their food-plant at and between the two posterior pairs of claspers, and this part of the larva, in relation to the food-plant, of course represents the point at which a twig is united with the branch immediately below the divergence. At such a point the bark of twig and branch are continuous, and anything which suggested a deep furrow between them would destroy the protective resemblance. At one point only in the body of a Geometer larva is there any necessity for maintaining apparent continuity with the food-plant, and at this point only in the larvæ which I have examined fleshy tubercles like those described above (in *Catocala*, &c.), are developed. In fig. 1 the

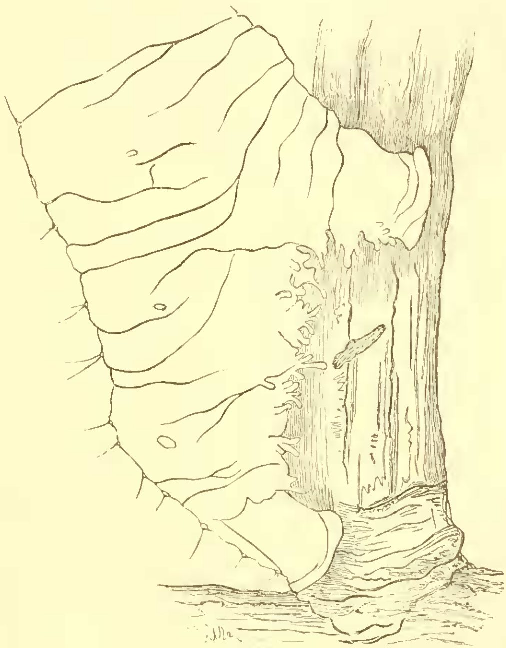
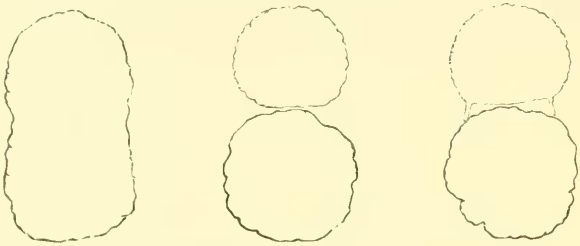


Fig. 1.

posterior part of the body of the larva of *Rumia cratægata* is shown (× 9 diameters), and the fleshy processes are seen to exactly correspond to that part of the body which would otherwise cause a dark shadow in the deep cleft between itself and the branch. The effect of the fleshy processes is diagrammatically shown in fig. 2, in which (*a*) represents a section across two branches immediately below the point at which they have divided, (*b*) represents a section across the larval body between the two posterior pairs of claspers, showing the formation of a deep cleft, while (*c*) shows how the outline of the larva on the branch is approximated to that of (*a*) by means of the processes. Although the cleft is largely filled up in (*c*), a considerable furrow remains, but this is not apparent



(*a*) (*b*) (*c*)
FIG. 2.

because of the light colour of the fleshy processes, which prevent the attention from being directed to the shadow which would otherwise indicate the position of the groove. The processes therefore attain the object of softening the contact between the larva and its food-plant in a two-fold manner, by partially filling up the cleft, and by neutralising the shadow in the groove which remains. I have also noticed the processes in the larva of *A. betularia*, and I believe that they are of very general occurrence in *Geometræ*. The appearance of such structures in the one small part of the larva where such a cleft exists and their absence elsewhere, together with their obvious function in this and the other cases, seem to render Prof. Meldola's explanation a matter of certainty.

δ. *An extreme instance of the specialisation of a larva to its normal food-plant.* — We occasionally meet with larvæ which are specialised in relation to the minute details of their peculiar food-plants, or of their commonest food-plants, if the larvæ occur upon more than one. Such specialisation in the details of protective resemblance would seem to imply an extremely ancient association of the larvæ with their food-plants, and it may occasionally aid us in deciding upon the ancestral food-plant of a larva out of the many species of plants which may be eaten. Such an ancestral association must have existed between the larva of *Deilephila Hippophaes* and its food-plant, *Hippophaes rhamnoides*, for not only are the colours of the leaves faithfully reproduced, but the characteristic orange berries are represented by an orange spot at the base of the caudal horn upon each side, as was pointed out by Weismann, and as I can confirm from my experience of the larva at Visp in Switzerland. In the case of *Rumia cratægata* it is similarly possible to affirm that hawthorn is the food-plant with which the larva has been longest associated out of the several species of plants upon which it also occurs. On Plate X., fig. 5 (natural size) a drawing was made of a living example of this larva as it rested upon a twig of hawthorn. It is at once seen that the dorsal tubercles placed on about the middle of the length of the larva very faithfully represent a superficially similar structure upon many of the side twigs of the food-plant. Not only do these projections occur towards the middle of the length of the twigs, but they are situated on the angle of a slight bend, a character which is also reproduced in the larval form. Furthermore, the mode in which the different varieties of the larva are coloured is almost exactly the same as in the varying twigs of this plant. The bark is covered by a thin superficial layer which is of a bluish-grey colour, while the deeper layers beneath are brown, or green, or mixed brown and green, becoming visible over a large part of the surface owing to the breaking away of the former layer. Hence the colour of the branches is brown or green, mottled with grey, and not only is this the exact appearance of the larva, but the way in which the colours are blended is precisely similar in the animal and the plant. The darker colours of the larva may be brown, or green, or mixed brown and green, mottled in all cases with bluish grey. Such remarkable specialisation to the details of single food-plant certainly warrants the suggestion that the association is very ancient,—that *Cratægus* is the ancestral food-plant of *Rumia cratægata*.

4. A further account of the defensive structures of the larva of Dicranura vinula.—In my last paper (Trans. Ent. Soc. Lond., 1886, Pt. II., June, pp. 156—158) I gave an account of defensive appearance and habits of the larva of *D. vinula*. I am now able to give a figure of the larva in the terrifying attitude (see Plate X.,

fig. 6, nat. size). The larva appears to depend entirely upon tactile stimuli for the direction in which to move its terrifying full-face, and towards which to eject the irritant acid secretion. Visual sensations appear to play no part as guides in the assumption of the defensive attitude. The large and full-fed larva which is represented in fig. 6 was only sensitive to tactile impressions, and the slightest touch upon either side or upon the back was always followed by a corresponding movement of the anterior part of the larva, and the attitude thus taken up on each occasion was maintained for some considerable time, although instantly altered when another part of the body was touched.

In the same paper (*loc. cit.*) I described a complex form of prothoracic "gland" which was everted by applying pressure to the larva of *Dicranura furcula*. I have now found that a similar "gland" is present in *D. vinula*; and I wish to correct an error in the description of this structure given in my last paper. The account was written from the memory of an observation made many months before in Switzerland, and it is wrong in describing the everted gland as consisting of six diverging processes. In reality two lateral processes—or everted gland-tubes—are present upon each side, while a median pouch represents the partially everted sac, in which the irritant secretion is stored. All are coloured green from the green blood which is forced into them, on eversion. These structures are most easily everted in *D. vinula* at the beginning of the last larval stage, a time when all the defensive structures appear to be at their highest state of functional activity. At this time the caudal filaments are large and brightly coloured, and are extremely sensitive; while later in the stage they decline in importance, and generally cease to be capable of eversion. The larva does not seem to be able to evert its prothoracic gland voluntarily, but very slight pressure is at this very sensitive period sufficient to cause eversion. It appears probable that this structure, starting as an ordinary gland, became voluntarily eversible like the ventral glands of *Crœsus* and the dorsal glands of the larvæ of *Liparidæ* described in the next section, and that the power of eversion has been very recently lost, as the larva has acquired the remarkable power of ejecting the intensely irritant secretion to a considerable distance by forcing it through the narrow chink with its closely approximated lips, which constitutes the mouth of the duct leading to the sac. Such a formidable means of defence may readily have supplanted the more usual method of eversion, a method which can only give rise to the discharge of vapour into the air, instead of a well-directed stream of fluid, which, if volatile, as it is in these larvæ, of course produces abundance of vapour.

The appearance of the everted gland is indicated in Plate X., fig. 7 (× 2 diameters), in which the head and prothorax of a larva in the sensitive period are shown from below. Of the four gland-tubes the anterior pair are seen to be much larger and longer than the posterior pair. The position of the structures corresponds with that of the horizontal slit-like mouth of the short duct leading to the sac, through which eversion takes place, and which is shown upon the red prothoracic margin of the head, below the true mouth, in fig. 6. In an earlier paper (Trans. Ent. Soc. Lond., 1885, Pt. II., August, p. 322) I have given an account of the eversion and introversion of the pink flagella of the larva of *D. vinula*. I have now studied the subject more thoroughly, and can add further details. In Plate X., fig. 8 (× 8 diameters) the left conical receptacle is seen from the left side, with its flagellum completely everted. Immediately above the receptacle the basal section of the flagellum is white or very faintly pinkish, and through this part the rest of the flagellum can be seen to pass during eversion and introversion. The withdrawn flagellum can also be seen with a little care in the receptacle itself. It follows from such a constitution that the summit of the receptacle when the flagellum is introverted represents the rim of a tubular depression, of which the lumen is bounded by the morphologically outermost,—the cuticular layers of the flagellum itself. In eversion the rim rises to successively higher levels as each section of the outer part of the flagellar cuticle passes over its edge, and becomes truly outermost in position, and, last of all, the apex is unfolded, and the rim then disappears. Conversely, in introversion the apex sinks, and a rim at once appears, which also sinks until the summit of the receptacle is reached. In fact, the structure affords an excellent example of a "pleurecbolic" introvert, "acrembolic" during introversion, very clearly described and distinguished from the converse type of introvert by Prof. E. Ray Lankester ('Encyclopædia Britannica,' article "Mollusca," p. 652). As far as I am aware, all the introverts in insects belong to this type. One result of this organisation is the extreme delicacy of the rim in the introverted organ, for the smallest injury causing a thickening or a slight adhesion on any part of the margin will entirely prevent eversion. And it is in this manner that the flagella usually become functionless: they are not otherwise injured in themselves, but are merely permanently introverted, and can easily be seen lying in the receptacle.

The organ is everted by forcing blood into it, and advantage was taken of this fact in obtaining the material from which fig. 8 was drawn. A loose ligature of silk was placed round the apex of the receptacle of a larva, and when the flagellum was fully everted on irritation the ligature was tightened, and the flagellum, being full of blood, was incapable of introversion. Another ligature was applied immediately below the former, and the receptacle divided between the two, and the flagellum was then drawn with the aid of a camera lucida. The structure was then hardened in a warm aqueous solution of mercuric chloride, and subsequently in spirit, longitudinal sections being taken through the apex imbedded after long soaking in melted paraffin. The structure of the organ, as shown by the sections, is represented in Plate X., fig. 9 × 188. The apparently smooth cuticle is seen to be covered with extremely minute spine-like processes. The cuticle itself is, as usual, made up of a homogeneous, superficial, and a finely lamellated deeper layer, of which the former is alone continued into the processes. Neither of these layers contain pigment in this part of the larva, but the pink colour is entirely due to the immediately subjacent hypodermis cells. These cells possess a fusiform outline when seen from the surface, while sections show them to be flattened and to overlap in an imbricated manner. The pink pigment is darkest round the margins of the cells, and especially at their apices. Beneath the cells is a very delicate layer which represents the "dermal" tissue in many other parts, and beneath this again is a space filled with blood in the everted organ, while in the centre is the retractor muscle, made up of several bundles arranged round an axial space, which contains a large ganglion. There is little doubt that the blood penetrates the axial space and between the bundles of the muscle. The muscular tissue consists of striated fibres, and the bundles are surrounded by a sheath which must be highly elastic. The ganglion cells are very large, and their processes are often seen to be continuous with nerve-fibres. The proportion of nervous to muscular tissue is very large, a fact which is doubtless correlated with the extraordinary rapidity and extent of the muscular contraction and relaxation during intro- and eversion respectively. The extent of contraction is so great that the length of the relaxed muscle must be some considerable multiple of its length when completely shortened. All the structural details above described are plainly indicated in fig. 9.

5. Additional eversible glands in larvæ. — I feel sure that these defensive structures are of constant occurrence in lepidopterous larvæ.

α. *The larva of Liparis auriflua.*—This larva, although well protected by its irritating hairs, also possesses two median dorsal eversible glands of an orange colour. In the commonest variety of this larva there is a red dorsal band traversed by a median black line, situated over the dorsal vessel. The black line everywhere divides the red band, except towards the anterior margins of the 6th and 7th abdominal segments, where, exactly between the two tubercles which bear the long black hairs on each segment, a bridge of the red colour unites the opposite halves into which the band is divided, and the glands are present upon these bridges, their orange colour being distinct against the surrounding red. Another variety of the larva only possesses the merest trace of the red band, and the orange glands are therefore peculiarly conspicuous against a black background. The glands are not often completely everted, but they are very sensitive to tactile impressions, and on stimulation a clear transparent secretion appears in the lumen, being probably raised by partial eversion. The secretion is not acid to litmus paper, but it possesses a peculiar and penetrating odour. These glands are, in the case of *L. chrysorrhœa*, alluded to by Duponchel, quoted in Stainton's 'Manual,' "A reddish tubercle on the back of each of the 11th and 12th segments." In this description the segments are wrongly numbered; they should be 10th and 11th. Newman, in 'British Moths,' alludes to the glands in both *L. chrysorrhœa* and *L. auriflua*: "The tenth and eleventh segments have a circular, wax-like, cup-shaped, scarlet spot on the very middle of the back." They are also described, in *L. auriflua*, as glands by Mr. A. H. Swinton in the Proceedings of the Entomological Society of London, who wrongly implies that their secretion is of value in providing a poison for the irritant hairs of the species. The glands are purely odoriferous, and have no means of discharging their fluid contents on to the hairs. Furthermore, it is probable that the hairs in this species are merely mechanical irritants: they are equally effectual for a long time after they have been shed by the larva, as I know from the experience of pulling to pieces an old cocoon in which the hairs were interwoven.

β. In the Liparidæ generally.—Finding the glands in *Liparis*, I examined the larva of *Orgyia antiqua*, and found similar structures in the same position. Last year I described a single gland on the 7th abdominal segment of *Dasychira* (*Orgyia*) *pudibunda*, evidently corresponding to the posterior of the two in the former species. I therefore asked Lord Walsingham to allow me to look through the preserved larvæ of *Liparidæ* in his collection. Lord Walsingham kindly allowed me to examine the larvæ, and greatly helped me in the search. All the *Liparidæ* were found to possess the glands, except the genus *Demas*, in which I could not detect them. Two glands occurred in all the larvæ of the other genera, except in *Dasychira* (for *D. fascelina* resembled *D. pudibunda* in only possessing the posterior gland). The glands were minute in *Psilura* (*Lymantria*) *monacha*, and small in *Hypogymna dispar*, while they resembled those of *L. auriflua* in all other British species. Examining some species of Indian *Liparidæ*, the two glands were found in *Lymantria concolor* (Walker), and where they were small and resembled those of our own *P. monacha*, to which the species is evidently closely allied. They were also found in *Chærotricha plana* (Walker), *Charnidas exclamationis*, in three species of the genus *Artaxa* (*A. vitellina, scintillans*, and *guttata* [all Walker]), and in *Dasychira dalbergiæ* (Moore). I was unable to find them in a few Indian larvæ belonging to this genus, but they may have been present and difficult to detect in the preserved larvæ. Thus the character is probably almost coextensive with the family. Stainton probably recognises this in the general description of the *Liparidæ*, given in the 'Manual,' containing this sentence: "Larva . . . frequently with two fleshy protuberances on the twelfth segment." As above stated, the glands occur upon the 6th and 7th abdominal segments, *i. e.*, upon the 10th and 11th segments of the other system of terminology. The single gland of our two British species of *Dasychira* helps to unite these in a single genus, and to separate them from other species, thus confirming the classification of Stainton's 'Manual' and controverting that of Newman. All these eversible glands are "pleurecbolic" and "acrembolic," like the flagella of *D. vinula*, and all must possess an axial retractor muscle. I have proved this by means of sections in the case of the ventral glands of the larva of the hymenopterous *Cræsus septentrionalis*, one of which, in a state of partial eversion, is shown in longitudinal section in Plate X., fig. 10, × 24·5. The axial retractor muscle (*r, m*, fig. 10) is made up of striated fibres.

6. On markings which frequently appear on larvæ before pupation, and which correspond in position to the underlying pupal wings. — When a larva is examined in the contracted quiescent state which precedes pupation, the lateral region of the meso- and metathoracic segments are seen to be swollen. This expansion is due to the underlying pupal wings which are formed as pouch-like diverticula from the body-cavity. The larval cuticle is easily stripped off an insect which has been kept in spirit, and the pouch-like rudimentary wings are then distinctly seen to be the cause of the swollen appearance. But the rapid morphological changes which are going on beneath the surface are often attended by other modifications of the superposed larval tissues, which are far more difficult to explain.

Thus in many larvæ the swollen lateral area of both segments is seen to have undergone a marked alteration in colour. Sometimes the pigment in the larval hypodermis disappears, and the areas are coloured by the green blood of the insect (e. g., *Selenia illunaria*, and in many other larvæ); but in other cases new pigment may be deposited in the larval cuticle, and an entirely new marking may thus make its appearance at the extreme end of the larval life. The most striking instance which has come under my observation is afforded by the bright green larva of *Gonoptera libatrix*, in which the convexity of each thoracic swelling becomes covered with a black patch, that upon the mesothorax being the larger and of a deeper tint. The appearance of the anterior part of the larva just before pupation is shown in Plate X., fig. 11 ($\times$ 2). Thin sections examined under a high power reveal the fact that the pigment is placed in the superficial layer of the cuticle, thus occupying the position in which black colouring-matter apparently always occurs. This formation of pigment at such a time, and in such a position, is of great physiological interest, for either the pigment itself or its factors must have traversed the lower thicker lamellated layer of the cuticle in order to reach the thin superficial layer, thus clearly showing that no part of the cuticle is beyond the reach of physiological processes while it forms the covering of the living larva. If there were a time in which the larval cuticle could be looked upon as a mere mechanical investment it would be at this very period, when it is to be shortly cast off, and when the larval hypodermis cells are elaborating, or are just about to elaborate, a new (pupal) cuticle beneath the surface. But at this very time we have the clearest indications that the larva has not lost its organic hold upon its superficial investment. It would be of great interest to carefully investigate the exact time at which the pigment appears, and to examine by means of sections its relation to the first formation of the pupal cuticle. It is impossible at present to form an opinion as to whether the appearance is of any significance in relation to the difficult question of the origin of wings, or whether (as appears more probable) it is merely an incidental result which attends the commencement of new activities by the hypodermis cells. In Plate X., fig. 12 × 10, a transverse section of the mesothorax of *G. libatrix* is represented, showing the superficial larval cuticle with the black pigment present in its outer layer over an area corresponding to the swelling, which is seen to correspond with the pupal fore wing, shown in section beneath and formed as a diverticulum from the body-cavity. The pupal body and wing is covered by its own partially formed cuticle, of which the rough superficial layer is complete while the lower lamellated layer is in process of development. The details of the larval and pupal cuticle and the hypodermis cells of this region are shown in Plate X., fig. 13 × 188. The cells are seen to be remarkably long, and their deep ends are prolonged into fibre-like processes, while their superficial extremities are continuous with a layer (coloured red in fig. 13) which represents the partially developed lamellated layer of the pupal cuticle.

7. Further notes upon the larva of Paniscus cephalotes.—(1). On August 1st I found an adult larva of *D. vinula* near Oxford, and eight eggs of *P. cephalotes* were attached to it in the following positions: one egg between the 3rd thoracic and 1st abdominal segment, six between the 1st and 2nd abdominal segments, and one between the 2nd and 3rd abdominal segments. The eggs were not crowded, but nearly all were attached to the left side of the larva. Three of the eggs (out of the six described above) were near the median dorsal line, on the purple band or its white border, one of these being attached on the right side of the middle line. I was very interested to find that the larva could evert its caudal tentacles, although they were comparatively small and unimportant as a means of defence, this being always the case after the first part of the last stage. On August 11th the eggs had all developed a few days, and the development began just as the larva ceased feeding and darkened. On August 9th I removed seven out of the eight parasitic larvæ while they were quite small, two being in the first stage and six just beginning the second. The larva which was left was unhealthy and soon died.

(2). On August 24th an adult larva of *D. vinula* was sent to me by Mr. W. H. Harwood: by the next day it had become brown, and had begun its cocoon. It had five eggs of *P. cephalotes* attached to it in the following positions: three eggs between the 2nd and 3rd thoracic segments, one of these being close to the median dorsal line and two rather farther down on the left side; two eggs at the same level as the two last described, between the 3rd thoracic and 1st abdominal segment. They had all just begun to develop before the larva arrived, but were in the first stage. When the larva darkened on the 25th the area to which the parasites were attached remained green. In this instance the larva was unable to protrude its flagella. There was every reason for the belief that the eggs had been attached to the larva before the last stage, and that DeGeer was right in saying that the skin can be changed without removing the eggs. Thus there were ragged remnants of skin round the ova at their points of attachment, and further, one of the prothoracic spiracles contained the main tracheal branch of the last stage, still lying in its lumen, seeming to show the difficulty with which the skin had been thrown off owing to the fact that it was pinned down, as it were, by the ova, so that ecdysis was only accomplished after the old skin had been torn to a considerable extent. There were minute scars near the ova, as if others had been attached to the larva, but had been torn out in ecdysis, or they may have been due to ineffectual attempts at oviposition on the part of the female *Paniscus*. In this case also all the ova were removed except one.

(3). On August 22nd I found another adult larva near Oxford, and to it only three ova were attached: one ovum between the 2nd and 3rd thoracic segments just below the white margin of the purple band; two ova between the 3rd thoracic and 1st abdominal segment, close together and in the same position. These latter ova were removed. The larva was unable to make use of its flagella. On August 25th the larva was about full-grown, and the parasites had just begun to develop.

On September 3rd larva (2) was examined, and the parasite was seen to have grown *immensely*, being far larger than any obtained last year. Its posterior extremity was detached from the egg-shell, and it was still eating the larva, although the latter was much shrivelled and was dead (recently). The *Paniscus* was very distended and glistening, being thus quite different from those observed last year, which after detachment lost the glistening appearance. The *Dicranura* larva had not been allowed to construct a cocoon, but No. (3) was contained in one, which was opened at this date, when it was seen that the single parasite was still small, although it was growing.

On Sept. 8th, when the former larva was beginning to spin, having ceased to feed a day or two earlier, I saw in the box a freshly formed and still undarkened pupa of some internal dipterous parasite. Hence the *D. vinula* had been simultaneously attacked by internal and external parasites of very different kinds. On Oct. 4th the box was opened, and it was found that the dipterous imago had emerged from the pupa many days before, and was dead. The species was ascertained to be *Tachina quadripustulata*.

On Sept. 11th the larva had constructed a large scaffolding of white silk over the remains of the *Dicranura* and the dipterous pupa. The larva No. (3) had now become very large, although not quite so large as the other; it had just begun to spin, having ceased to feed at about this date. From the previous observation of this larva it was seen that all the increase in size which follows an unusual supply of nourishment takes place *after* detachment, and that the larvæ are of nearly uniform size when they are detached. The length of the larva at this date was 22·5 mm., when rather stretched and very nearly straight.

On Sept. 16th the larva was rather smaller, having become slightly shrunken during the process of spinning a scaffolding. At this date it was drawn from two points of view, and it is seen in Plate X., fig. 14 (ventral view), and fig. 15 (lateral view), both figures being of the natural size. The silk spun by both the larvæ was white at first, but subsequently became dark. No. (3) did not construct a cocoon, but expended its silk in making a large scaffolding in the chip-box, but the central depression in which the larva now lies has the form of a furrow with well-defined sides, and probably represents the beginning of a cocoon. Larva No. (2), as it wandered over the chip-box spinning a scaffolding, came upon the hard cocoon which had been spun by the *D. vinula*, and entered through the hole by which the latter had been removed. In the smaller cavity it constructed a perfect oval cocoon. This entirely confirms my conclusions of last year, that the larvæ fail to make cocoons in a comparatively large space, because all their silk is exhausted in the scaffolding.

Thus larva No. (2) fed during a period of about fourteen days, and the other for about seventeen days; so that the duration of growth is precisely similar to that of the larvæ described last year (also extending from fourteen to seventeen days), although the size attained was far less in the latter case. The conclusion that the amount of growth is independent of the duration of the whole feeding period is also shown in the fact that the larger of the two larvæ (1886) ceased to feed in the shorter time. It is also interesting in relation to the same conclusion that larva No. (2) killed its host in eleven days, while in 1885 the *Dicranura* larva lasted through the attack of seven parasites during twelve days. On the subject of the size of these two larvæ, Mr. E. A. Fitch informs me that size is so entirely irregular among the imagos of the *Ichneumonidæ* that it cannot be adopted as any criterion of specific identity. It is exceedingly interesting to find so perfect an adaptation to the necessarily uncertain amount of food obtainable in the larval stage. I look forward with interest to the appearance of the imagos of my larvæ, for they have probably reached the upward limit of attainable size, inasmuch as the *Dicranura* larvæ did not seem to be completely eaten when the *Paniscus* larvæ ceased to feed.

I am now able to add the duration of the pupal period in *Paniscus*. In my last paper I described six larvæ (1885) as pupating May 17th—25th. On June 15th three imagos emerged, another appeared on the following day, and the remainder a few days later. Thus the pupal period lasts for about four weeks. Each imago directly after emergence ejects short white cylinders of excreta, which from their appearance are probably some product of nitrogenous metabolism. It is thus seen that these imagos appear some weeks before the time at which the larvæ of *D. vinula* have arrived at the stages of growth in which they are liable to the attacks of these parasites. A number of cocoons of *D. vinula* were kept under the same conditions as the *Paniscus* larvæ and pupæ, with the result that the eggs laid by the imagos of the former hatched at the time when the *Paniscus* imagos emerged. I endeavoured to keep the latter insects alive in glass cylinders, until the *Dicranura* larvæ were advanced in size, but they only lived for about a week. The mature larvæ of *Tæniocampa gothica* were offered to them, and on one occasion I witnessed an attack made upon one of these by a virgin female *Paniscus*. The struggling larva was firmly held by the hooked feet of the hymenopteron, while the mandibles of the latter were deeply embedded in its body, so that it bled freely; at the same time the sheaths of the horizontal ovipositor were held erect, as if the organ were about to be used. At this critical point I was obliged to leave in order to catch a train, but I afterwards found that no eggs had been affixed to the larva, which had died in consequence of the injuries inflicted upon it. I certainly gained the impression that the *Paniscus* was partially eating the larva, for so severe a bite would of course have entirely prevented the latter from acting as food for the offspring of the *Paniscus*. Furthermore, I have not found any scar on the *Dicranura* larvæ with eggs attached to them, which would indicate such severe treatment.

I wish now to correct a mistaken account which I gave last year of the ovum and the newly-hatched *Paniscus* larva. The mistake was due to the fact that the ova were partially hatched when I first examined them. In Trans. Ent. Soc. Lond., Pt. II., June, 1886, p. 164, I thus described the ovum:—"The free anterior pointed end of the ovum is marked off from the rest by a distinct line, and after development begins it remains attached to the young larva as a black and shining head-shield." The fact is that the unhatched ovum is rounded anteriorly, and exhibits no lines upon its surface, but in hatching it splits along the lower surface, corresponding to the ventral line of the enclosed larva, the line of separation passing upwards over the anterior and on to the front part of the superior surface of the black shell of the ovum. The head of the larva partially protrudes through the anterior part of the fissure thus made, and it is black and shining on its upper surface, exactly resembling the shell of the ovum. Gradual growth brings the head completely out of the ovum, being separated from it by the white larval body; but for many hours the head can alone be seen on an examination of the ovum from above, and at such a time it exactly presents the appearance described in my last year's notes. Furthermore, the head is not black and shining at any other larval stage, so that my mistake was very natural. The position of the young larva

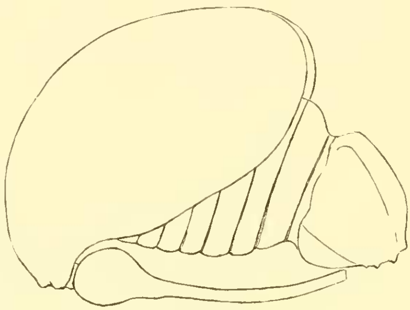


Fig. 3.

relatively to the egg-shell is shown in fig. 3; at the stage of growth which is represented the head is just outside the shell, and separated from it by one or two of the thoracic segments. It can be readily imagined that when the head is alone seen between the valves of the shell, which it exactly resembles in colour, the whole suggests an egg-covering marked by sutural lines. The harmony in colour is doubtless protective, for it renders the young larva indistinguishable from the egg during the earliest period of growth. The head is seen in the figure to be relatively large and well-developed; it is probable that a minute examination may show more distinct traces of the sense-organs and other structural features than in the later stages, and it is to be expected that these external hymenopterous parasites will preserve clearer indications of the ancestral non-parasitic forms from which they have been derived than those which are presented by the more degenerate ento-parasitic species. Now that I have the material I hope to investigate the structure of *Paniscus* larvæ by means of sections.

8. A special point in the protective attitude of the imago of Gonoptera libatrix. — The shape and colour of this moth forcibly suggest the appearance of a red leaf spotted with a few white bosses of fungoid

growth. The time of emergence and the habit of hybernation in the perfect stage correspond with the period of year at which the resembled objects form a predominant feature in nature. The moth is eagerly pursued and keenly relished by birds, so that it is of the greatest importance that the protective resemblance should be as perfect as possible, and that any indispensable structure which would interfere with the resemblance should be as far as possible concealed in the attitude of rest. On examining the moth I was very interested to find that the eyes are completely covered by a tuft of long hairs, which droop from the base of the antennæ when the latter are directed backwards, and are themselves concealed beneath the wings in the protective attitude. When the moth is about to fly the antennæ are brought forward, and the same action raises the tufts and uncovers the eyes, so that both pairs of sense-organs are rendered efficient simultaneously. The base of the left antenna, with its tuft of hairs, is shown in Plate X., fig. 16, $\times$ 24·5. It is likely that the tufts may be of use in defending the eyes from dust, &c., as well as in preventing the brilliancy of these organs from interfering with the protective resemblance. Instances of an analogous arrangement, with the latter significance, are found in the gecko and the chamæleon, the strong protective resemblance being in these cases necessary for the capture of prey rather than the avoidance of enemies. The capture being largely dependent upon sight, the eyes are very large, and would tend to render these animals highly conspicuous. Hence in the gecko the pupil is (except in dim light) a narrow chink with very irregular margins, while all the rest of the exposed part of the eye is coloured in such a manner as to harmonise with the general surface of the animal, rendered inconspicuous by its strong resemblance to the stone which it frequents. In the chamæleon the arrangement is even more perfect, for the large eyes are covered with skin, except for a small aperture opposite the pupil, through which the animal can look. This skin is directly continuous with that of the rest of the body, and, like it, can be changed in tint so as to correspond with the colour of surrounding surfaces.

9. The comparatively late emergence of female moths from the pupa.—Every entomologist who has bred lepidopterous insects in the hope of pairing them in order to obtain eggs must have noticed that the great difficulty with which he has to contend is the fact that the males tend to emerge before the females. I have noticed this for several years, and in the case of all the species which I have employed in large numbers, and I know that others have had a similar experience. At first sight it would appear that this want of uniformity must be a disadvantage to the species, for large numbers of males must die before the females appear, and during the time when the latter are only beginning to emerge in small numbers. But, on the other hand, a more than compensating advantage is doubtless gained by the complete rivalry among a large number of males for each of the females as they emerge, so that in the majority of cases success in courtship is gained through the possession of qualities which are of advantage to the species, and not merely through the circumstance of emergence at an appropriate time.

10. The hereditary transmission of pink tubercles on the larvæ of Saturnia carpini. — The following notes I owe almost entirely to the kindness of my friend Dr. F. A. Dixey. On July 25th, 1885, eighty larvæ of this species were sent to Dr. Dixey from Norfolk, where they had been found feeding on meadow-sweet. The larvæ were mostly in the last stage, or the last but one, and after their arrival in Oxford they were fed upon willow. The ground colour of these in the last stage but one, whenever observed, was of a light bright green, but in the last stage it varied from this colour to a dull and dusky green. The black markings were also very variable in the last stage, being, as a rule, especially small in the bright green larvæ. In some larvæ the black rings were incomplete, and were occasionally reduced to a mere black line round each tubercle. The longitudinal black marks, as a rule, only occurred in the dull green larvæ. In seventy-six larvæ the tubercles were yellow, varying from orange to lemon-yellow, and the lighter tubercles were generally found upon the bright green larvæ. In three larvæ the tubercles were pink, without a trace of yellow or orange; in one the

tubercles were pure white. Of the three larvæ with pink tubercles, one was recognised from its size to be a female, and it was of a dull green colour, with the black markings largely developed. The other two were similarly recognised as males, and they were both of the brightest green colour, but with the black markings well developed (unusually so for so light a ground colour). The perfect insects emerged during the last ten days of April, 1886, and 120 eggs were obtained from the female moth which was developed from the larva with pink spots, the male parent being derived from one of the two pink-spotted larvæ just described. The larvæ emerged on May 23rd, 1886, and were fed upon hawthorn. During their first stages they showed a distinctly gregarious habit, and persistently sought the side of their glass cage, which was turned towards the light. Eighty of the larvæ were given to me, while the remainder were reared by Dr. Dixey. Of these forty, thirteen were found in the last stage to have yellow or orange tubercles, twenty-seven to have pink spots like the parents. The black segmental rings were not imperfect in any of the forty larvæ, as was so often the case in the original batch of larvæ. In this they completely resembled their parents. The green ground colour varied, but was mostly bright like that of the male parent. One larva spun a cocoon with apparently no valvular opening. Nearly all the larvæ had a diarrhœal discharge immediately before spinning, but this appeared to be entirely normal, and to be unconnected with any unhealthy condition. The eighty larvæ given to me were partially used for physiological investigations, but forty-eight became sufficiently advanced in the last stage to note the colours of the tubercles, which were found to be pink in thirty-seven larvæ. The results can therefore be tabulated as follows :—

1885. 80 larvæ, of which three (or 3·75 per cent.) possessed pink tubercles.

1886. 88 larvæ, of which 64 (or 72·7 per cent.) possessed pink tubercles.

It should be added that my larvæ were exposed to surroundings of different colours, but that the tubercles and the black markings were entirely unaffected, while the dullness or brightness of the green ground colour certainly seemed to be influenced by dark or light surroundings. While the great majority of my larvæ possessed the uniformly developed well-marked black bands described by Dr. Dixey, in a few individuals these markings were present to a very slight degree.

11. RELATION BETWEEN PHYTOPHAGOUS LARVÆ AND VARIOUS SPECIES OF FOOD-PLANT.—One of the most interesting things about insects is their extraordinary specialisation in relation to plants, and the complete interdependence between these widely separated groups of organisms. Not the least interesting feature of this relationship is the fact that so many species of phytophagous larvæ are rigidly limited to a few or often to only a single species of food-plant. If such larvæ are offered other food-plants it is well known that they will generally starve without touching them. And yet there can be no doubt that the food-plants must have been often extended or changed as the range of a species altered, and, although such change may be frequently in the direction of allied or representative species of plants, this is by no means always the case. Thus, taking a single instance, the common food-plants of *S. ocellatus* are sallow and apple, the occasional food-plants laurel and poplar. But if a larva becomes so specialised in relation to a food-plant that it will starve without touching another species there seems to be a great barrier in the way of any alteration, and the continued abundance of the animal would seem to be endangered by a double series of risks, *i. e.*, those which beset the animal itself, and those which beset the plant upon which it depends. Many observations, however, tend to prove that the rigid specialisation largely grows up in the life of each individual, and is therefore not inherent in the species. This seems to be shown by the following observations:— The larvæ of *S. populi* feed commonly upon poplar, rarely upon sallow and laurel: during the past season I offered laurel to some half-grown larvæ which had been previously fed upon *Populus nigra*, and, although left without other food for some days, the laurel was untouched. The larvæ similarly refused *Populus alba*. So also *S. ligustri* commonly feeds upon privet, lilac, and ash, but it has been occasionally found upon holly; and I have unsuccessfully offered the latter food-plant to

larvæ which had been previously fed upon privet, &c. The converse relation does not hold, for Mr. Grut informs me that a larva which he found upon holly ate privet with complete readiness. So also *S. ocellatus* found upon sallow will always eat apple, and *vice versâ*; but I feel sure that in either case it would starve without touching laurel or poplar. The last observation which has come under my notice is the most remarkable. In 1885 I found a company of half-grown larvæ of *P. bucephala* feeding upon hazel, and I offered them elm and *Salix triandra*, both of which were untouched; while they readily ate oak and *Salix cinerea* or *S. smithiana*. In this case elm is a very common food-plant of the species, perhaps the commonest at Oxford, where the larvæ were found.

It therefore seems certain that the young larva on hatching is in a far less specialised condition, as regards its food-plants, than that which it will subsequently reach. And this conclusion is supported by further direct evidence, for it is well known that young larvæ will nibble leaves of plants upon which the species has never been found, and may sometimes grow for a considerable time upon such food; while conversely the half-grown larvæ offered some new food do not usually give themselves the chance of becoming adapted to it, for as a rule they will starve without nibbling it in the least. There is not much difficulty in imagining the conditions under which a change of food-plant might occur without the most obvious cause, *i. e.*, alteration in range of distribution. The instinct of laying eggs is far stronger than that of laying them upon any particular species of plant, for it is well known that in confinement moths will lay eggs upon any surface which is at hand. Similarly a deformed female moth could not seek a scattered food-plant, but would be compelled to lay its eggs in a limited area. So also, in the case of rare plants, any larva wandering far before pupation would render it possible that the moth might not find the plant at all, and under these circumstances it could not wait beyond a certain period without laying its eggs; and the same facts would probably hold for the last eggs laid by many strong-flying species. Again, in certain cases it is possible that the female moth may have been deceived by the superficial resemblance between plants, although, as a rule, the instinct is very accurate in this respect. Thus it has occurred to me that the remarkable association of sallow and apple, as the normal food-plants of *S. ocellatus*, may have been due to the considerable superficial resemblance between the wild crab (*Pyrus malus* var. *acerba*) and some of the broad-leaved sallows (such as *Salix caprea* or *S. cinerea*). There can be very little doubt after the above-described observations that holly is more recent as a food-plant of *S. ligustri*, and laurel in the case of *S. populi*, and such cases help us to understand how changes have occurred. The ready growth of a complete specialisation between such larvæ and their more ancestral food-plants, and the less complete specialisation to the more recent food-plants, is probably the direct result of the far greater age and frequency of the former relationship, so that in this case heredity works with instead of against the specialisation which grows up in the life of each individual. And probably, for the same reason, the change from one ancestral food-plant to another, or from a recent to an ancestral food-plant, when larvæ are half-grown, is rendered possible in those cases in which it has been proved to occur. But whether these suggestions be well founded or not, the main facts of this section must be held as established by observation,—that the newly-hatched larva is free to form special relations with occasional or rare food-plants which cannot be formed by the more mature larva in which such relations have already grown up towards a commoner food-plant. And this observation obviously goes a long way towards the explanation of those changes of food-plants which we know must have often occurred.

12. The origin of carnivorous habits in phytophagous larvæ.—Several observations make it probable that cannibalism or carnivorous habits tend to arise in larvæ, and have probably arisen in the past, out of the necessities which follow the scarcity of the normal food. During the summer of 1886 I was keeping large numbers of larvæ under conditions which rendered it probable that the food-supply would sometimes fall short. In order to investigate the colour-relation between larvæ and their surroundings, coloured glass cages and bags of coloured glazed lining were made use of; within these

coverings the condition of the food-plant could not be watched, and sometimes it withered, or was eaten earlier than I expected. Thus the larvæ were sometimes without food for a few days, and it was then found that *S. ocellatus* had lost their caudal horns, while in some cases the dorsal surface of the posterior part of the body had been also nibbled. This habit of nibbling off the caudal horns of other individuals is well known in this species and in *D. vinula*, but I do not think that it has been recognised as the result of hunger and as an obvious tendency towards cannibalism. This is proved by the fact that other lots of larvæ, always abundantly supplied with food, were either not injured at all or only in a very small proportion of cases. In one instance I kept some larvæ of *D. vinula* and *S. ocellatus* together in a blue cage, and on one occasion the food-plant had withered, and while it was being renewed I observed that a *D. vinula* was gnawing the thoracic leg of an *S. ocellatus*, and when the two were separated the former soon returned and seized one of the claspers in its mandibles, and bit it until it bled. Under similar circumstances I have found an almost full-grown larva of *A. betularia* which was engaged in swallowing a small larva of the same species. The small larva was held tightly in the clasp of the thoracic legs, and nearly half of it had disappeared when the observation was made.

These uniform results of the absence of food in all three species of purely phytophagous larvæ which have been placed under such circumstances seem to offer a probable explanation of those instances in which cannibalism is well known to occur.

13. The young larvæ of Vanessa urticæ and Saturnia carpini seek light.—Dr. Dixey informs me that his larvæ of *S. carpini*, when young, always assembled on the side of the cylinder which was turned towards the light, and I have made a similar observation in the case of the young larvæ of *V. urticæ*. In both cases rotation of the cylinders was followed by a corresponding change in the position of the larvæ. Both these larvæ are dark coloured when young, so that the observation, as far as it goes, supports Lord Walsingham's conclusions as to the advantage gained by the

absorption of radiant energy by larvæ. It would be well to test the theory by interposing a transparent athermanous screen between the larvæ and the source of light.

14. The movements of larvæ guided by an appreciation of the force of gravitation.—The following observation seems to admit of no escape from the conclusion that larvæ are guided by this sense, which must be of great importance to them when they have been blown off their food-plants, or have fallen after being disturbed. During the past summer I had great opportunities of observing the larvæ of *Vanessa urticæ.* It was necessary, for some experiments which I was then conducting, that the larvæ of the different companies should be kept apart, and accordingly they were placed in separate boxes. But a large company contains from 100 to 200 individuals, and it was found exceedingly difficult to put the last larvæ in the box without losing or injuring many others which had been previously captured, and which crawled up the side of the box and endeavoured to escape when the lid was removed. The explanation suggested in the title of this section then occurred to me, and I at once tested it by turning the box upside down in my pocket, when the larvæ immediately crowded to the bottom of the box, which was then uppermost. On another occasion I witnessed the practical use of this sense of direction in the case of the same species. While the individuals of a large company were being removed from a nettle-bed, about a dozen larvæ fell to the ground and escaped among the crowded leaves. Returning in the course of half an hour all the larvæ were found upon the tops of the nettles, having evidently commenced to reascend without any loss of time. Another instance of the same sense of direction is seen in the behaviour of larvæ (such as *Pygæra bucephala*) which have been blown off trees in the neighbourhood of walls and houses, for under such circumstances the larvæ obey the instinct to crawl upwards upon any adjacent surface, whatever it may happen to be, and they may often be seen patiently ascending some object which does not lead to their food-plant. But under natural conditions the larvæ are not equally liable to be misled by this sense of direction,

and under all circumstances it is controlled by that other sense which enables the larva to recognise its food-plant as soon as it reaches it.

Description of Plate X.

Fig. 1. Natural size. The mature larva of *Smerinthus ocellatus*, seen from the right side. The larva was found on *S. triandra*, and possessed the most developed system of red spots which I have yet seen. The figure shows that all three rows were highly developed, the upper row being represented on every segment anterior to the 8th abdominal; the middle row possessing in addition a spot upon the latter segment, while the lower row was quite complete, all the claspers being distinctly marked.

Fig. 2, × 2 diameters. The head of a mature larva of *Smerinthus populi*, seen from the right side. The patches of dark shading upon the head indicate the position of the red markings. The larva possessed a remarkably developed system of red spots, which extended on to the head itself in the positions shown in the figure. The chief masses are seen to be in the area of the ocelli, represented as a semicircle of black points, and on the apex of the head.

Fig. 3. Natural size, seen from the right side. An apparently mature Chærocampoid *Sphinx* larva, brought from Celebes by Dr. Hickson. The larva combines, in an interesting manner, the characteristics of many genera of *Sphingidæ*. The well-formed eye-like mark on the 1st abdominal segment, together with the correlated form of the anterior part of the body and the head, rendering possible the well-known terrifying attitude,—all are as in *Chærocampa*. The oblique stripes, with their dark borders, the traces of shagreening, and the subdorsal persistent for its whole length, especially resemble *Smerinthus* and the younger stages of *Sphinx*. The shape of the caudal horn is peculiar, but recalls that of the latter genus, while the fact that the shagreening is far more prominent upon this structure than upon any other part of the body also obtains in other genera, although it is perhaps most characteristic of *Acherontia*. The white dorsal and lateral spots are probably very ancestral features recognisable in the younger stages of *Sphinx* and *Smerinthus*. The living larva was green in colour.

FIG. 4. Natural size. A mature larva of *Amphidasis betularia*, seen from the left side. The figure represents a common green variety of this variable larva, and it is seen that in this, the usual attitude of rest, the larva is supported by holding a portion of the food-plant with its last pair of thoracic legs, instead of by the thread which is usually spun by the larvæ of *Geometræ* for this purpose.

FIG. 5. Natural size. The mature larva of *Rumia cratægata*, as seen from the right side attached to its food-plant—hawthorn—in the natural attitude of rest. The larva is recognised by the supporting thread, which, however, from its colour and fineness, does not attract attention in nature. The figure was drawn from an actual specimen of the larva on its food-plant, and it indicates the remarkable resemblance between the structural details of the animal and the plant upon which it most commonly occurs. The twigs resemble the larva in colour, in shape, and in direction. About in the middle of the majority of the twigs there is a prominent projection, which is almost exactly imitated by the dorsal tubercles of the larva; the processes form the crown of a very slight bend in both, while the ends of the twigs greatly resemble the head of the larva. Such a specialised protective resemblance would seem to be the product of a very prolonged association of the larva with this species of plant.

FIG. 6. Natural size. The mature larva of *Dicranura vinula* in the terrifying attitude, as seen from the left side. The larva had been irritated on the left side of its body, and, in obedience to the tactile stimulus, had assumed the attitude represented in the figure. In addition to the terrifying appearance being thus brought to bear upon the point from which the attack is made, the mouth of the gland secreting formic acid is also directed so that an enemy would probably be struck by the discharged fluid. The caudal flagella are represented as everted to their full extent, although the power of using these weapons is generally lost in the mature larvæ.

FIG. 7, × 2 diameters. The head and prothorax of a larva of *Dicranura vinula* towards the beginning of the last stage, looked at from below. At this stage of growth slight pressure applied to the larva causes the eversion of the gland-tubes which secrete the formic acid, and of the median sac in which the fluid is stored. There are seen to be four tubes, the anterior pair being longer and wider than the posterior pair. The position of the everted organs is seen to correspond with that of the horizontal slit-like mouth through which eversion takes place, and shown upon the red margin of the prothorax below the head in fig. 6.

Fig. 8, × 8 diameters. The left conical receptacle of the larva of *Dicranura vinula*, as seen from the left side, with its flagellum completely everted. Comparison with fig. 6 indicates that the flagellum curves towards the dorsal aspect of the larva. On the dorsal side of the base of the receptacle the anal flap is seen, and a tubercle (of which there are two) terminating in a bristle, and made use of in removing the fæces. The base of the flagellum is faintly coloured and transparent, so that the rest of the organ can be distinctly seen passing through this part during introversion. As introversion commences with the apex of the organ, the latter is seen to enter the transparent portion when the pink part is reduced to half its length. In the normal position of rest the transparent base is also introverted, and the deeply coloured part of the organ can be dimly seen lying in the semitransparent receptacle. The latter is covered with black patches, each of which bears a tubercle terminating in a bristle.

Fig. 9, × 188 diameters. The apex of the flagellum of the larva of *Dicranura vinula*, drawn so as to show the arrangement of its structural details. From the base up to the horizon A—A the superficial characters are shown; the cuticle, which appears smooth to the naked eye and with very low powers, is seen to be prolonged into very numerous fine sharp short processes (*c*); these are also seen in section above A—A, and they are shown to be processes of the superficial cuticular layer. Between A—A and B—B the hypodermis cells (*h. c.*) are seen from the surface, the cuticle having been removed. Above A—A the cuticle is seen in section around the rest of the structure, and it consists of the two normal layers, a superficial cuticular layer, which is non-laminated (*s. l. c.*), and a deep cuticular layer, which is finely laminated (*d. l. c.*) Both are quite transparent in this organ, although the former contains the black pigment in other parts of the larva. The whole of the pink pigment is contained in the flattened hypodermis cells (*h. c.*), and, as indicated in the drawing, it is darkest round the margins of the cells, and especially at their apices. Above B—B a longitudinal section along the middle line of the organ is shown; an oblique view of a transverse section of the structures beneath the cuticle, through half the organ, being represented immediately below B—B. The structures on the left side of the drawing are alone shaded in the longitudinal section. The hypodermis cells (*h. c.*) are seen to be flattened and to overlap each other. Beneath the cells is a delicate layer (B, *l.*) representing the thicker "dermal" connective tissues in many other parts. Beneath this there is a space filled with blood in the everted organ. Then follows the retractor muscle made up of several bundles arranged round an axial space containing a large ganglion. The muscle bundles (*r. m.*) consist of striated fibres, and they are surrounded by a sheath (*m. s.*), which must be highly elastic. Occupying the axial space there is seen to be a ganglion made up of large ganglion cells (*g. c.*) and nerve-fibres (*n. f.*). The proportion of nervous to muscular tissue is seen to be very large.

FIG. 10, × 24·5 diameters. One of the eversible ventral glands of the larva of *Crœsus septentrionalis*, as seen in longitudinal section. The gland is represented as almost completely everted, the apex being still retracted. The layers are represented diagrammatically: (*s. l. c.*) = superficial non-laminated cuticular layer; (*d. l. c.*) = the deep laminated layer; (*h. c.*) = the hypodermis cells. The retractor muscle is shown at (*r. m.*); its fibres are striated.

FIG. 11, × 2 diameters. The head and four anterior segments of the larva of *Gonoptera libatrix*, as seen from the left side in the contracted state before pupation. The larva had been taken out of its cocoon. Two large black patches are very conspicuous on the second and third thoracic segments: no trace of these markings was present in the larva before the cocoon was spun. The line parallel with the dorsal contour of all segments except the anterior thoracic is the subdorsal, which was present in the younger larva, and still remains distinct. The black patches exactly cover the pupal wings which are developed beneath.

FIG. 12, × 10 diameters. A transverse section through the middle of the second thoracic segment of the larva of *Gonoptera libatrix*, showing the relation of the black patch indicated in the last figure to the developing pupal wings. Only the right half of the section is complete, the median line being indicated by the dotted line A—A. The digestive canal is indicated at (*d. c.*), the commissural strands of the ganglionic cord at (*n. c.*) The pupal cuticle is represented by (*p. c.*), and the larval cuticle by (*l. c.*) The pupal wing (*p. w.*) is seen to be developing as a pouch-like diverticulum of the body-cavity. The black patch (*b. p.*) is shown to be due to pigment in the superficial part of the larval cuticle; its extent is seen to correspond with that of the rudimentary wing beneath.

FIG. 13, × 188 diameters. A portion of the developing wing of the last figure, together with the larval cuticle which covers it, seen in transverse section. The larval cuticle consists of the two normal layers, of which the superficial one (*s′. l′. c′.*) is seen to contain the whole of the pigment of the black patch, while the lower lamellated layer (*d′. l′. c′.*) is coloured by staining reagents. This high magnification shows that the larval surface is rough, although it appears perfectly smooth to the naked eye. Of course there are no hypodermis cells beneath the larval cuticle, for these structures have sunk to a lower level after forming the cuticle of the pupal wing, which now intervenes between them and the larval cuticle. These cells (*h. c.*) are extremely long and narrow when their whole length is shown in the section: their bases become attenuated and pass into fine fibre-like processes: their upper parts become continuous with an apparently homogeneous layer (*d. l. c.*), which represents the partially formed lower lamellated layer of the cuticle. Above this is the previously formed superficial layer (*s. l. c.*), which is ochreous in colour, but which quickly deepens into black on exposure to air when the larval skin is thrown off. This latter layer is seen to be much thicker and rougher than that of the larva.

FIG. 14. Natural size. The larva of *Paniscus cephalotes*, externally parasitic upon the larva of *Dicranura vinula*. The larva is seen from beneath, and it is of very exceptional size. The *D. vinula* larva was attacked by several of these parasites, of which all but one were destroyed, and the latter therefore appears to have attained the maximum size, for the host was not quite demolished.

FIG. 15. Natural size. The same larva, seen from the left side.

FIG. 16, × 24·5 diameters. The base of the left antenna of the imago of *Gonoptera libatrix*, as seen from the left side in the attitude of rest. In this attitude the main part of the antenna passes backwards beneath the wings, while a tuft of hairs rising from the base is brought over the eye of the moth, When the moth is disturbed the antennæ are brought forward, and the same action raises the tuft and uncovers the eyes. When at rest the brilliancy of the eyes is thus prevented from interfering with the very perfect protective resemblance to a dead leaf, and the eyes are also defended from dust, &c., especially during the prolonged rest of hybernation, which in this species takes place in the imaginal stage.